COLUMBIA POWER TECHNOLOGIES

power from the next wave

Attachment 4

Intermediate TAEP calculations

Title	Intermediate TAEP calculations
Document No.	
Version	1.0
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Version	Date	Summary
1.0	17 November, 2015	

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1 INTRODUCTION

The WEC performance at DD-I stage differs from DD-P for three reasons:

- Improved generator efficiency due to reduced generator air gap,
- Reduced mechanical friction losses due to improved estimates of rail bearing friction, and
- Lowered center of gravity due to reduction in generator mass.

The differences above do not warrant new simulations, which would require computational resources, but instead are handled via post-processing of the DD-P simulation results. Note that all simulations and calculations were carried out according to 'Energy Production Assessment for DOE LCOE and SPA Reporting'.

Generator efficiency is naturally handled in post-processing; the inputs to the DD-I efficiency model are generator speed and generator torque.

The difference in frictional torque (due to improved rail bearing system) is assumed to be applied as generator torque. As the shaft torque is unchanged by the friction reduction, the dynamic response of the WEC can be assumed to be unchanged.

The lowered center of gravity (c.g.) is ignored in the DD-I results. Previous investigations indicate that performance improves with a lower c.g.; however the difference in c.g. was relatively small and do not warrant new simulations at the DD-I stage.

2 PERFORMANCE AND LOSS MATRICES

Performance matrices are depicted, with simulation conditions specified by the midpoint of each populated cell in the matrix. Mechanical power extracted (Figure 1) is calculated before any mechanical or electrical losses. Electrical power captured (Figure 2) is calculated as grid quality power, after all mechanical and electrical losses.

Losses are calculated as described in 'Energy Production Assessment for DOE LCOE and SPA Reporting'. PTO losses (Figure 3) include mechanical losses from the main bearings, idler bearings, and seals. Generator losses (Figure 4) include mechanical losses from the novel rail bearing system and electrical losses from the generator. Ancillary losses (Figure 5) include losses from power electronics, hotel loads and transformer.

The sea states where the fore-in-aft configuration was modeled are depicted in matrix form in Figure 6.

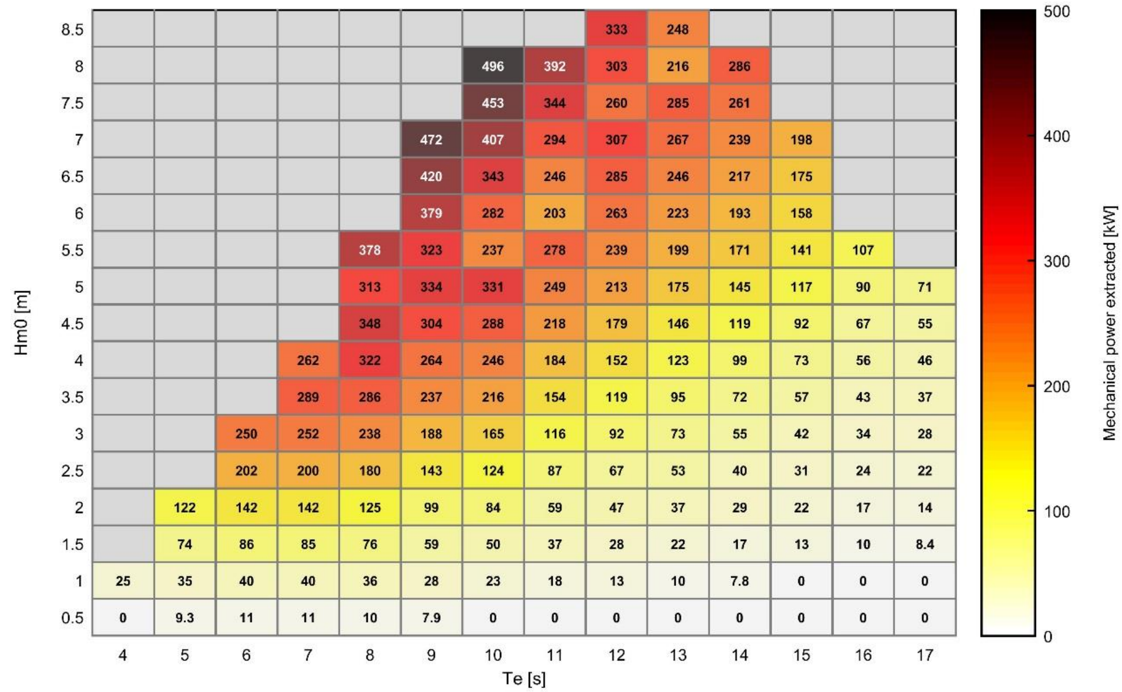


Figure 1 – Performance matrix of mechanical power extracted.

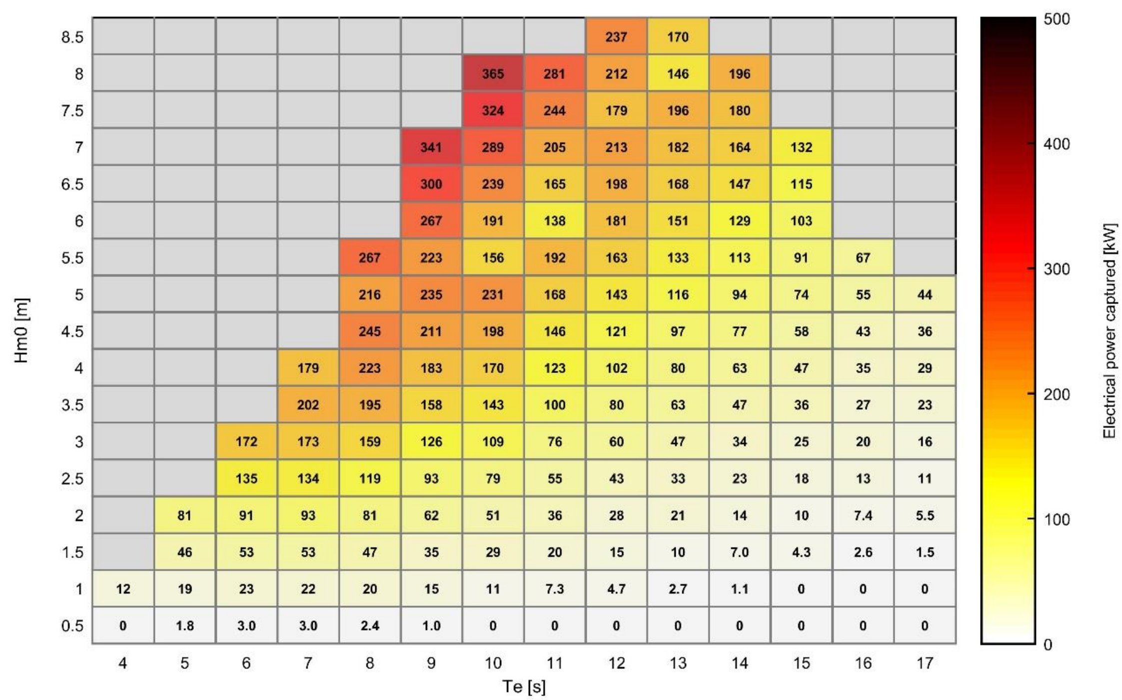


Figure 2 – Performance matrix of electrical power captured.

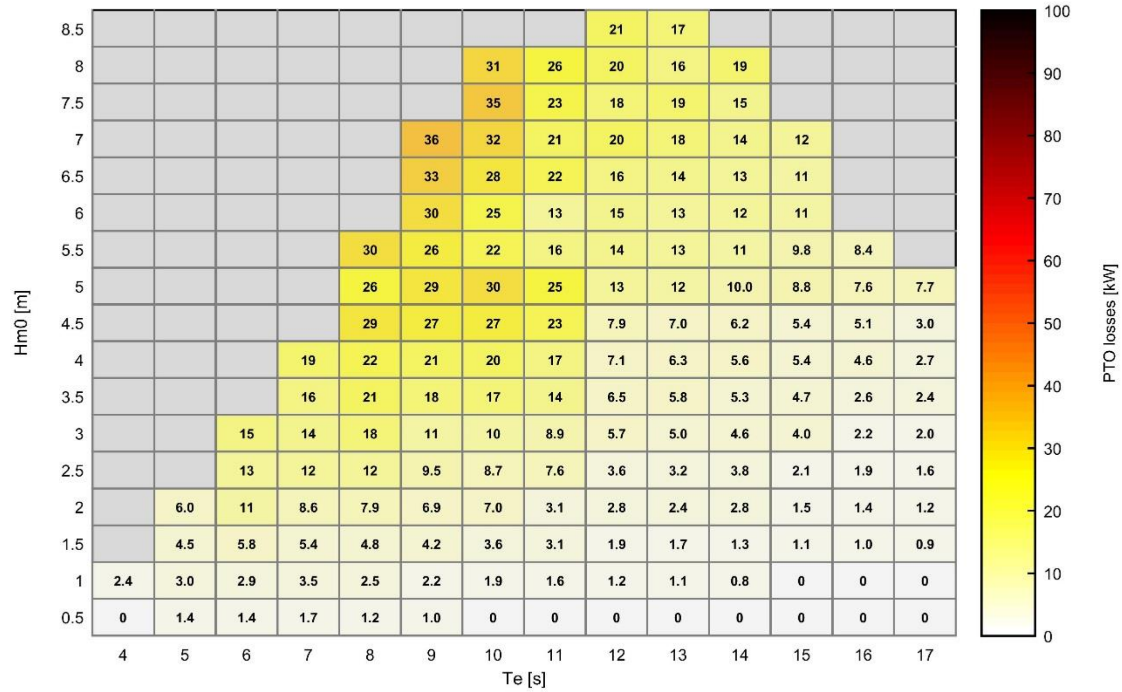


Figure 3 – Matrix of PTO losses.

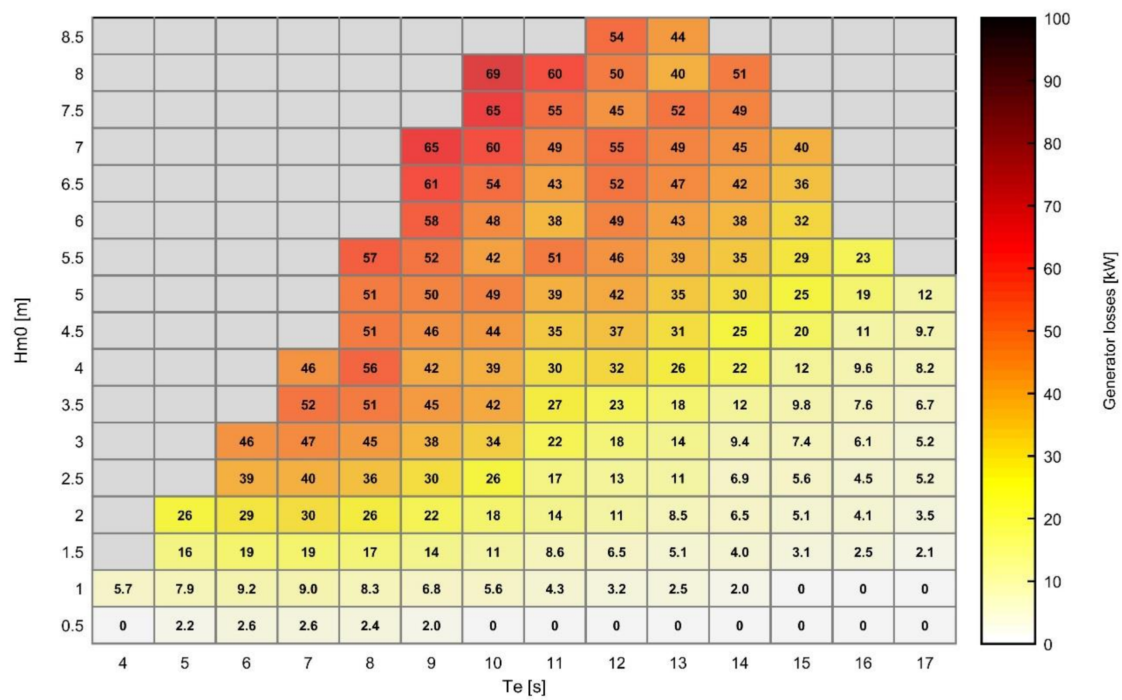


Figure 4 – Matrix of generator losses.

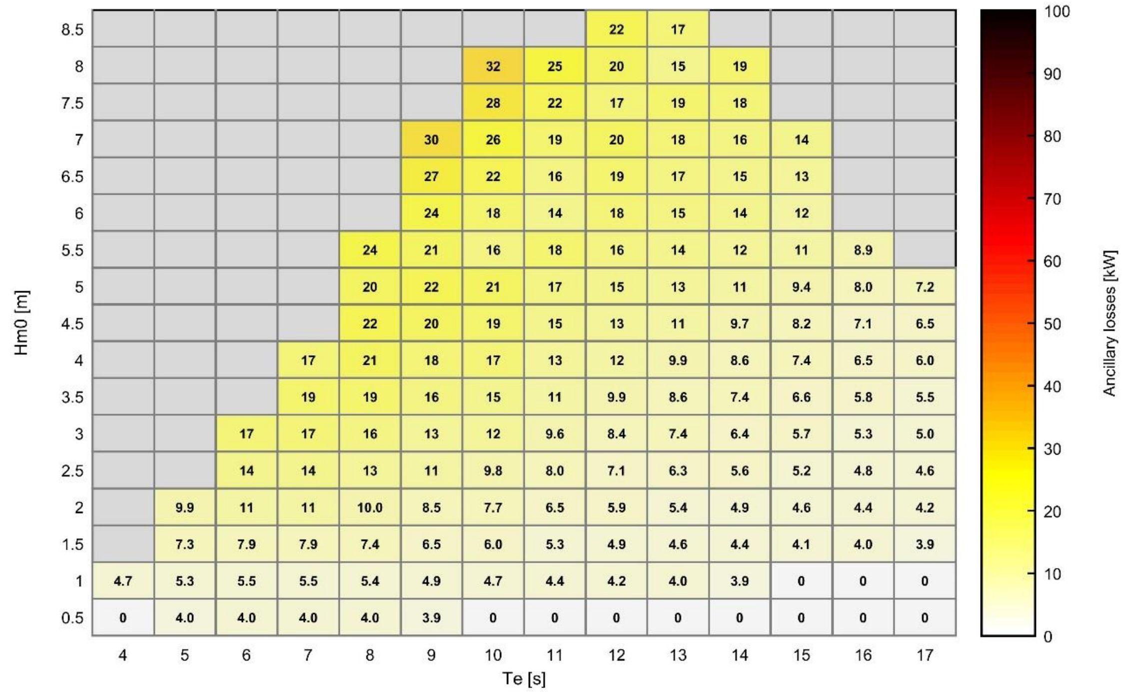


Figure 5 – Matrix of ancillary losses.

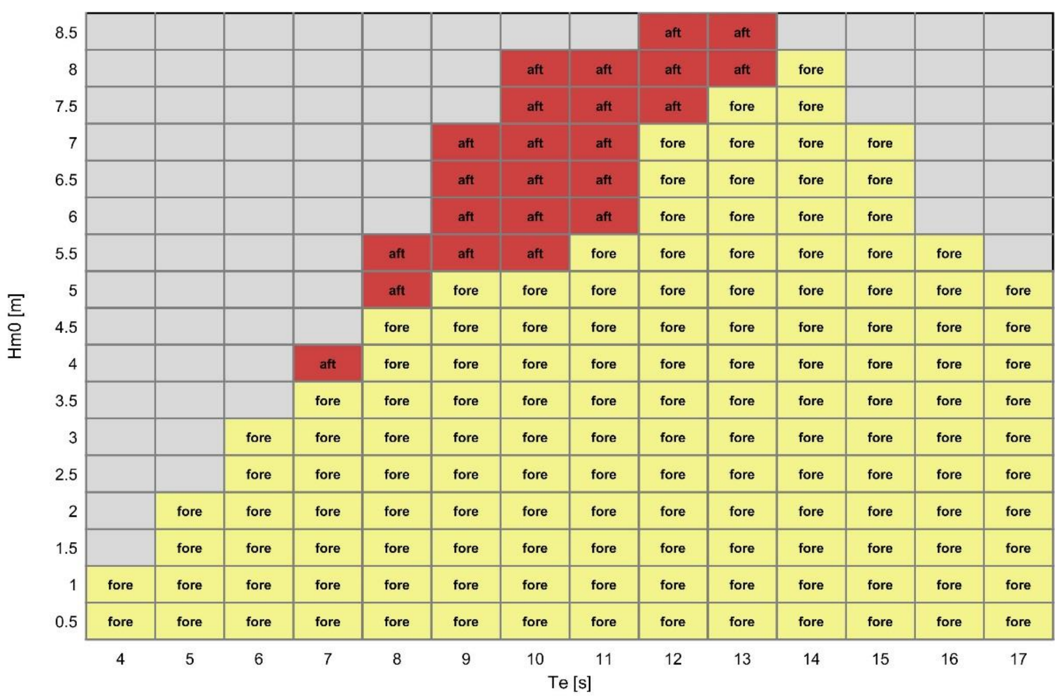


Figure 6 – Fore float configuration depicted in matrix format.

3 AEP CALCULATIONS

3.1 Summary

TAEP at various stages of power conversion chain are given below for four resources. Further details are given in the following sections for each site. Availability and transmission losses are accounted for in the main body of 'MS13.1 EE-0006399 LCOE and SPA'.

Table 1 – Mean annual power at four sites of interest.

	Mean Power [kW]			
Site	Mech extracted	Mech into generator (pre rail bear)	Elec out of generator	Elec captured
DOE Reference (NDBC 46212)	106	98	77	68
Hawaii (WETS B)	94	87	68	59
Oregon (NDBC 46050)	129	120	95	85
Ireland (AMETS A)	183	169	136	123

Table 2 – TAEP at four sites of interest.

	Theoretical Annual Energy Production [MWh]			
Site	Mech extracted	Mech into generator (pre rail bear)	Elec out of generator	Elec captured
DOE Reference (NDBC 46212)	926	862	675	596
Hawaii (WETS B)	822	767	594	521
Oregon (NDBC 46050)	1134	1053	833	743
Ireland (AMETS A)	1600	1482	1191	1076

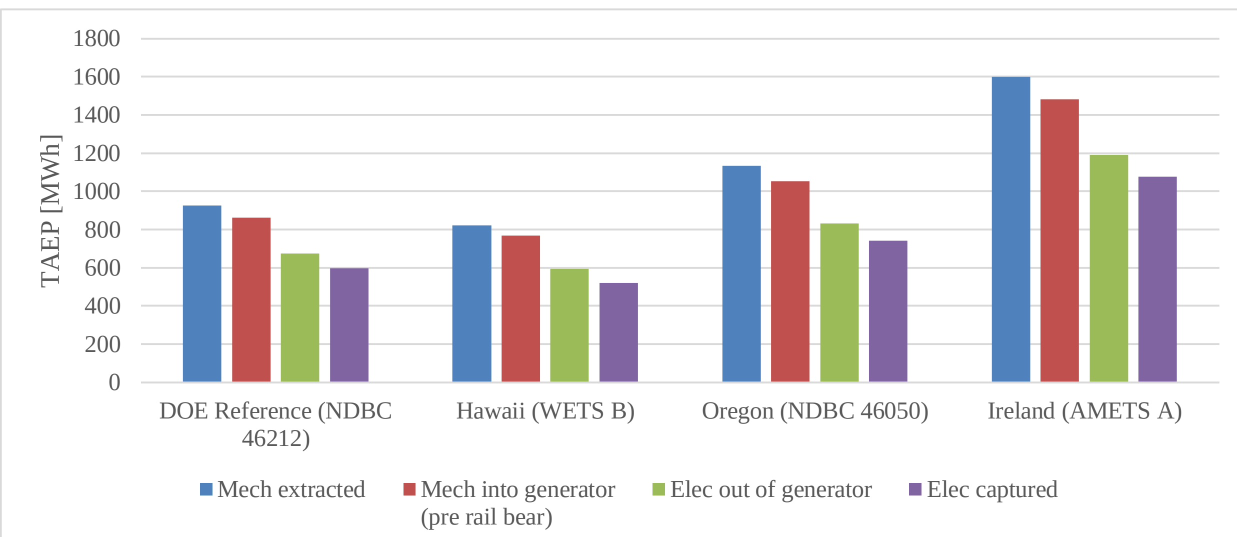


Figure 7 – TAEP at four sites of interest.

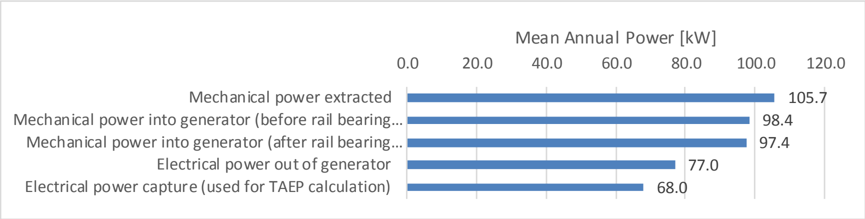
3.2 DOE Reference (NDBC 46212)

Table 3 – Mean annual power and losses for DOE reference site.

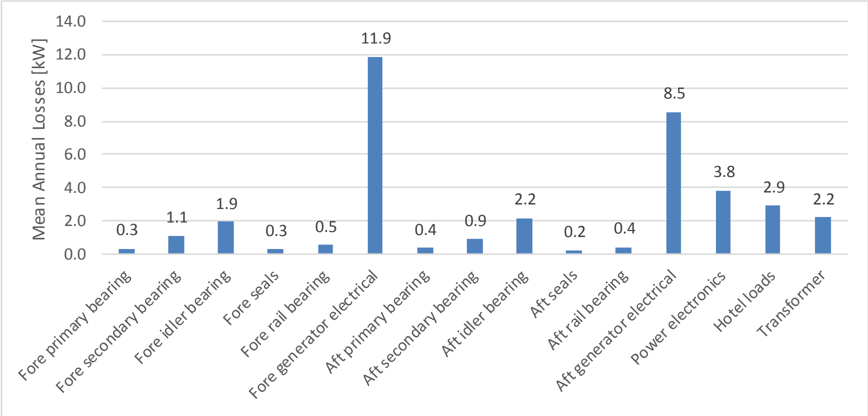
Source data: L2228-N2673 and L2228-N2674

Working folder:Z:\Engineering\LandRAY\Design Files\0000 Design Conditions and Response\LCOE

Power Annual Power [kW]	CA (DOE ref)
Mechanical power extracted	105.7
Mechanical power into generator (before rail bearing losses)	98.4
Mechanical power into generator (after rail bearing losses)	97.4
Electrical power out of generator	77.0
Electrical power capture (used for TAEP calculation)	68.0



Losses [kW]	CA (DOE ref)
Fore primary bearing	0.3
Fore secondary bearing	1.1
Fore idler bearing	1.9
Fore seals	0.3
Fore rail bearing	0.5
Fore generator electrical	11.9
Aft primary bearing	0.4
Aft secondary bearing	0.9
Aft idler bearing	2.2
Aft seals	0.2
Aft rail bearing	0.4
Aft generator electrical	8.5
Power electronics	3.8
Hotel loads	2.9
Transformer	2.2



Losses by stage [kW]	CA (DOE ref)	Efficiency	Efficiency is with respect to...
PTO mechanical losses (prim/sec bearings + idler bearings + seals)	7.3	93%	Mech power extracted
Generator losses (rail + generator electrical)	21.4	78%	Mech power into gen (before rail losses)
Generator rail losses	0.9	99%	Mech power extracted
Generator electrical losses	20.4	79%	Mech power into gen (after rail losses)
Ancillary losses (PE + hotel + Transformer)	8.9	88%	Elec power out of generator

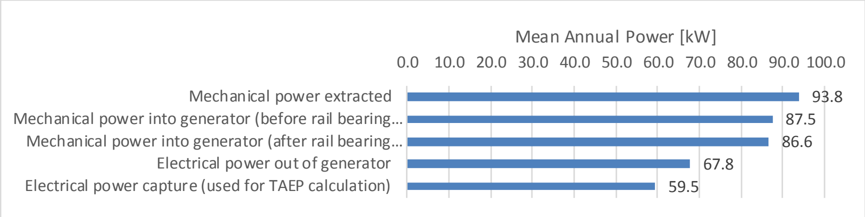
3.3 Hawaii (WETS B)

Table 4 – Mean annual power and losses for Hawaii (WETS B).

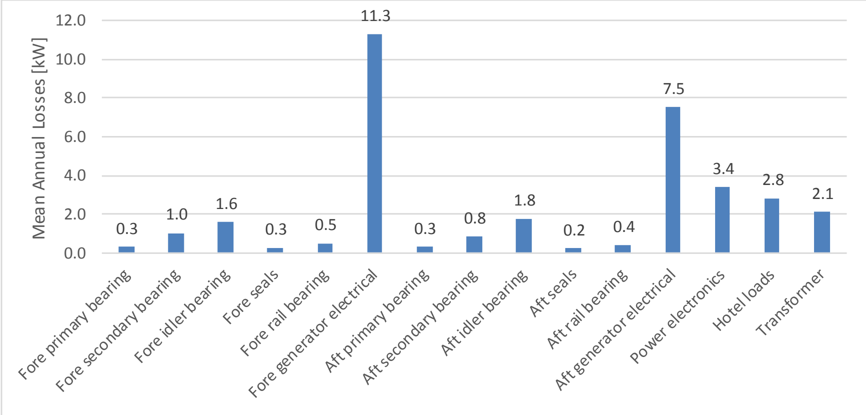
Source data: L2228-N2673 and L2228-N2674

Working folder:Z:\Engineering\LandRAY\Design Files\0000 Design Conditions and Response\LCOE

Power Annual Power [kW]	HI (WETS)
Mechanical power extracted	93.8
Mechanical power into generator (before rail bearing losses)	87.5
Mechanical power into generator (after rail bearing losses)	86.6
Electrical power out of generator	67.8
Electrical power capture (used for TAEP calculation)	59.5



Losses [kW]	HI (WETS)
Fore primary bearing	0.3
Fore secondary bearing	1.0
Fore idler bearing	1.6
Fore seals	0.3
Fore rail bearing	0.5
Fore generator electrical	11.3
Aft primary bearing	0.3
Aft secondary bearing	0.8
Aft idler bearing	1.8
Aft seals	0.2
Aft rail bearing	0.4
Aft generator electrical	7.5
Power electronics	3.4
Hotel loads	2.8
Transformer	2.1



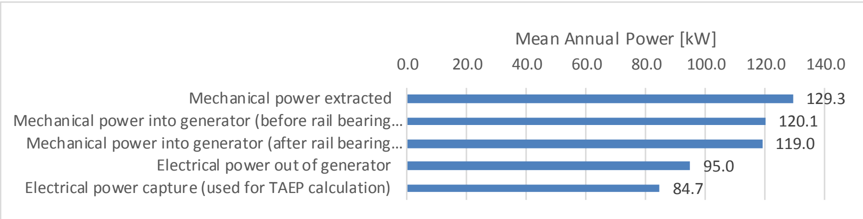
Losses by stage [kW]	HI (WETS)	Efficiency	Efficiency is with respect to...
PTO mechanical losses (prim/sec bearings + idler bearings + seals)	6.3	93%	Mech power extracted
Generator losses (rail + generator electrical)	19.7	77%	Mech power into gen (before rail losses)
Generator rail losses	0.9	99%	Mech power extracted
Generator electrical losses	18.8	78%	Mech power into gen (after rail losses)
Ancillary losses (PE + hotel + Transformer)	8.3	88%	Elec power out of generator

3.4 Oregon (NDBC 46050)

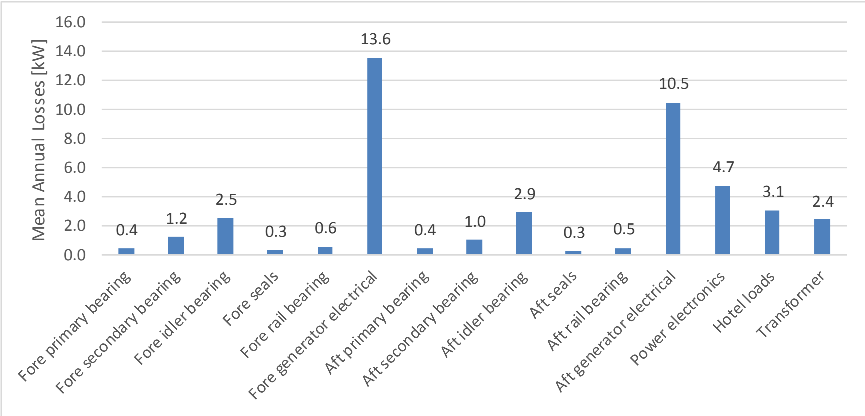
Table 5 – Mean annual power and losses for Oregon (NDBC 46050).

Source data: L2228-N2673 and L2228-N2674
Working folder:Z:\Engineering\LandRAY\Design Files\0000 Design Conditions and Response\LCOE

Power Annual Power [kW]	OR (ndbc46050)
Mechanical power extracted	129.3
Mechanical power into generator (before rail bearing losses)	120.1
Mechanical power into generator (after rail bearing losses)	119.0
Electrical power out of generator	95.0
Electrical power capture (used for TAEP calculation)	84.7



Losses [kW]	OR (ndbc46050)
Fore primary bearing	0.4
Fore secondary bearing	1.2
Fore idler bearing	2.5
Fore seals	0.3
Fore rail bearing	0.6
Fore generator electrical	13.6
Aft primary bearing	0.4
Aft secondary bearing	1.0
Aft idler bearing	2.9
Aft seals	0.3
Aft rail bearing	0.5
Aft generator electrical	10.5
Power electronics	4.7
Hotel loads	3.1
Transformer	2.4



Losses by stage [kW]	OR (ndbc46050	Efficiency	Efficiency is with respect to...
PTO mechanical losses (prim/sec bearings + idler bearings + seals)	9.2	93%	Mech power extracted
Generator losses (rail + generator electrical)	25.1	79%	Mech power into gen (before rail losses)
Generator rail losses	1.1	99%	Mech power extracted
Generator electrical losses	24.1	80%	Mech power into gen (after rail losses)
Ancillary losses (PE + hotel + Transformer)	10.2	89%	Elec power out of generator

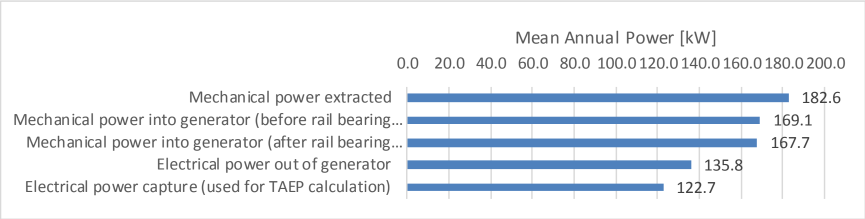
3.5 Ireland (AMETS A)

Table 6 – Mean annual power and losses for Ireland (AMETS A).

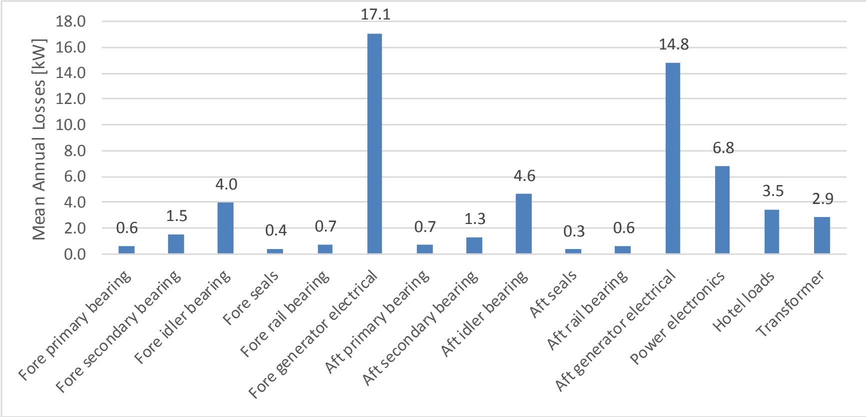
Source data: L2228-N2673 and L2228-N2674

Working folder:Z:\Engineering\LandRAY\Design Files\0000 Design Conditions and Response\LCOE

Power Annual Power [kW]	IRL (ametsA)
Mechanical power extracted	182.6
Mechanical power into generator (before rail bearing losses)	169.1
Mechanical power into generator (after rail bearing losses)	167.7
Electrical power out of generator	135.8
Electrical power capture (used for TAEP calculation)	122.7



Losses [kW]	IRL (ametsA)
Fore primary bearing	0.6
Fore secondary bearing	1.5
Fore idler bearing	4.0
Fore seals	0.4
Fore rail bearing	0.7
Fore generator electrical	17.1
Aft primary bearing	0.7
Aft secondary bearing	1.3
Aft idler bearing	4.6
Aft seals	0.3
Aft rail bearing	0.6
Aft generator electrical	14.8
Power electronics	6.8
Hotel loads	3.5
Transformer	2.9



Losses by stage [kW]	IRL (ametsA)	Efficiency	Efficiency is with respect to...
PTO mechanical losses (prim/sec bearings + idler bearings + seals)	13.5	93%	Mech power extracted
Generator losses (rail + generator electrical)	33.3	80%	Mech power into gen (before rail losses)
Generator rail losses	1.3	99%	Mech power extracted
Generator electrical losses	31.9	81%	Mech power into gen (after rail losses)
Ancillary losses (PE + hotel + Transformer)	13.1	90%	Elec power out of generator